



Forest Health Protection

Pacific Southwest Region

Northeastern California Shared Service Area

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To: District Ranger, Feather River Ranger District, Plumas National Forest

Subject: Evaluation of stand conditions with respect to forest insects and disease within the Mooreville project, Plumas National Forest (FHP Report NE18-03)

At the request of Clay Davis, District Planner, and Ken Neeley, Forester, Feather River Ranger District, Danny Cluck, Forest Health Protection (FHP) Entomologist, visited the Mooreville project area with district staff on September 19, 2017. The objective was to evaluate the current forest health conditions within the project area, discuss what influence these conditions would have on stand management objectives and provide recommendations as appropriate. Clay Davis, Ken Neeley and Erik Aplan, Forestry Technician (Fuels), accompanied me to the field.

Key findings:

- Overstocking is putting many stands, especially on poorer sites, at risk to elevated levels of bark beetle-caused tree mortality during periods of drought.
- An increase in white fir has reduced the number of shade intolerant pines on some south facing slopes and ridge tops.
- White fir mortality is occurring at slightly elevated levels across the project area.
- Mixed conifer stands have also experienced elevated levels of ponderosa and sugar pine mortality caused by western pine beetle and mountain pine beetle.
- High fuels loads, consisting of an abundance of dead-down trees and live and dead brush have put some stands at risk to increased fire behavior.
- White pine blister rust is infecting sugar pine, increasing the susceptibility of mature trees to bark beetle attack and negatively impacting regeneration.
- Thinning and prescribed fire are highly recommended throughout the project area to reduce tree density and surface and ladder fuel levels. Specific recommendations are provided in this evaluation.

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Description of the project area

The Mooreville project area is located ~2 miles west and southwest of La Porte, CA at elevations ranging between 3,700 and 5,900 feet (39.681883N and 121.022552W). Annual precipitation ranges between 70 and 90 inches. Most of the area is comprised of Sierra mixed conifer consisting of white fir (*Abies concolor*), Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), sugar pine (*Pinus lambertiana*), incense cedar (*Calocedrus decurrens*), red fir (*Abies magnifica*), California black oak (*Quercus kelloggii*) and Pacific madrone (*Arbutus menziesii*). Most of the lower elevation stands are pine dominated mixed conifer while higher elevation stands are mostly fir dominated mixed conifer. Shade-tolerant pine species are mostly restricted to the overstory with limited regeneration due to overcrowding and dominance of white fir.

Project objectives

The Mooreville project proposes to reduce the risk of insect and disease-caused tree mortality through mechanical thinning. Fuels reduction and maintenance would be accomplished with mastication and prescribed burning. White fir will be removed in favor of retaining other tree species. The residual stands will be more open, increasing the amount of available soil moisture and sunlight for individual trees.

Forest insect and disease conditions

Agents/hosts observed during this site visit:

- Recent scattered white fir mortality caused by the fir engraver beetle (*Scolytus ventralis*) (Figure 1).
- Ponderosa pine mortality caused by western pine beetle (*Dendroctonus brevicomis*). This was also picked up by FHP aerial detection survey (Figure 2)
- Mountain pine beetle (*Dendroctonus ponderosae*)-caused mortality of sugar pine, often associated with white pine blister rust (Figure 3).
- Heterobasidion root disease, caused by *Heterobasidion occidentale*, in white fir at various levels throughout the project area (Figure 4).
- True fir dwarf mistletoe (*Arceuthobium abietinum* f. sp. *concoloris*) in white fir.

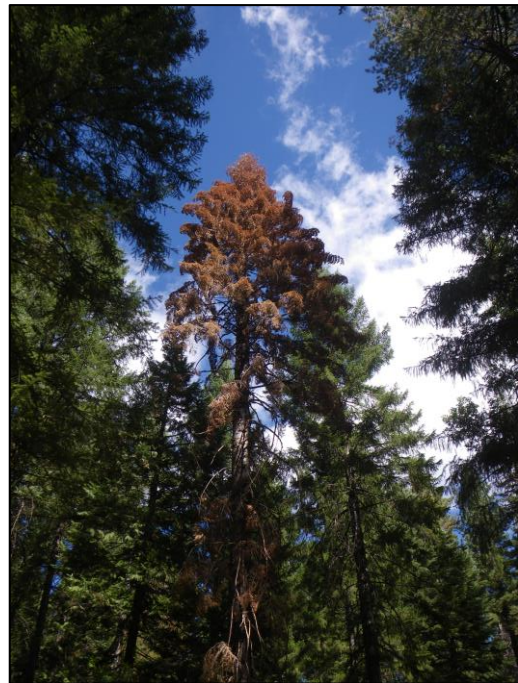


Figure 1. White fir killed by fir engraver beetle

Stand conditions and tree mortality related to recent and future climate trends

Most of the forested areas in the Mooreville project area are in an overstocked condition and experienced an elevated level of tree mortality caused by bark beetles during the recent drought (Table 1 and Figures 5 – 8). Aerial detection surveys have identified an increase in tree mortality for the project area in response to the extremely dry water years of 2014 and 2015. Elevated

levels of bark beetle-caused tree mortality in the project area, as well as in the rest of the Sierra Nevada range, are strongly associated with periods of below normal precipitation and high stand density. This mortality combined with the existing high stand density has resulted in heavy fuel loading in some areas and a corresponding increase in the risk of stand replacing wildfire.

Figure 2. Group killing of ponderosa pine by western pine beetle. Google imagery date of 6/29/2017.

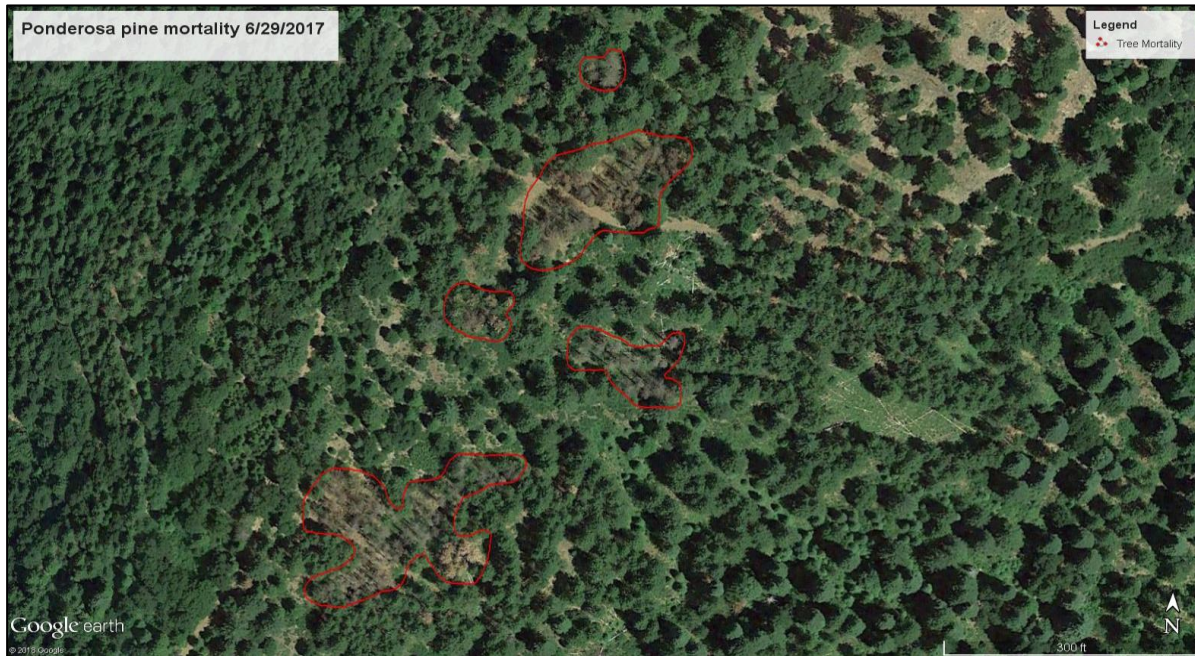


Figure 3. White pine blister rust infected sugar pine killed by mountain pine beetle.



Figure 4. Heterobasidion root disease infected white fir killed by fir engraver beetle.

Figure 5. Areas with tree mortality mapped by Aerial Detection Surveys (ADS) in 2017.

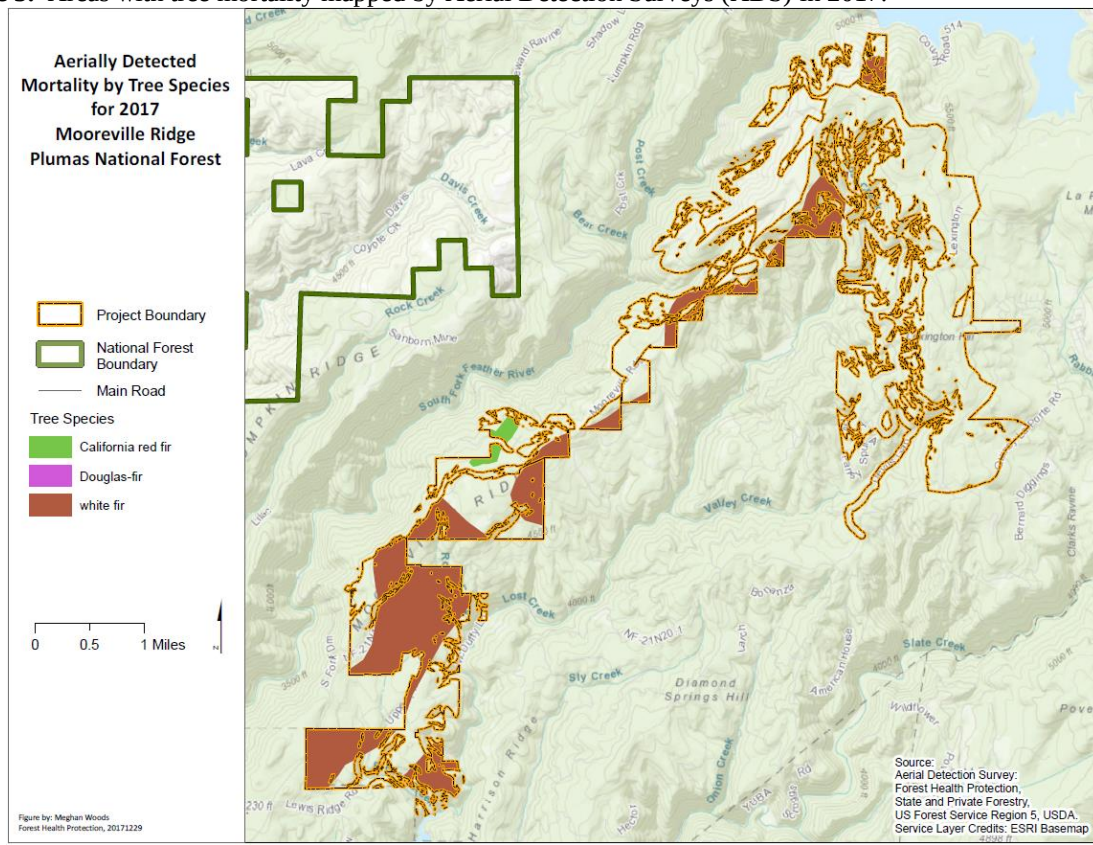


Figure 6. Areas with tree mortality mapped by Aerial Detection Surveys (ADS) between 2008 and 2017.

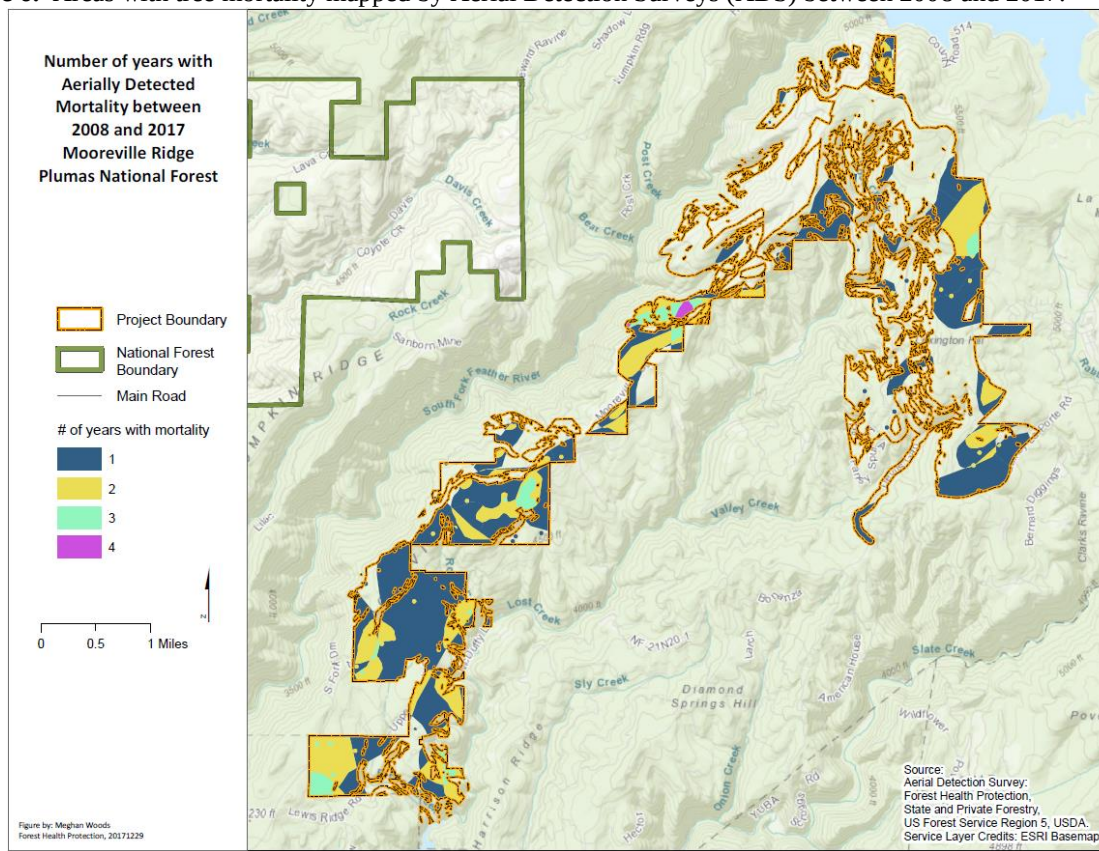


Figure 7. Cumulative dead trees per acre mapped by Aerial Detection Surveys (ADS) between 2008 and 2017.

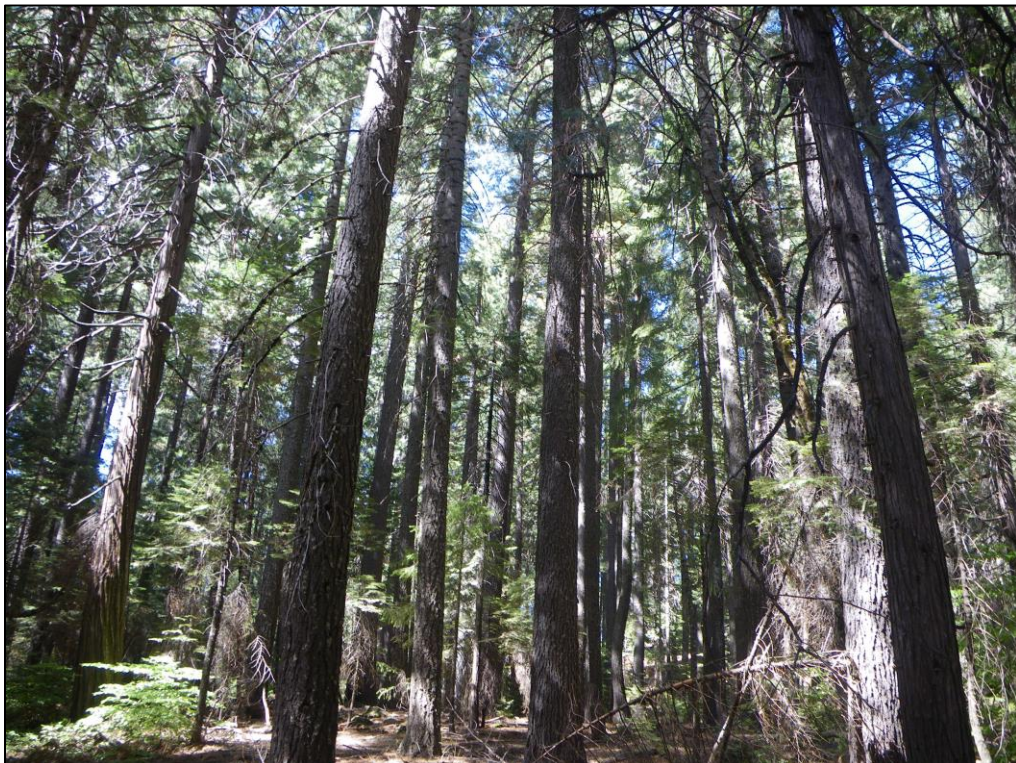
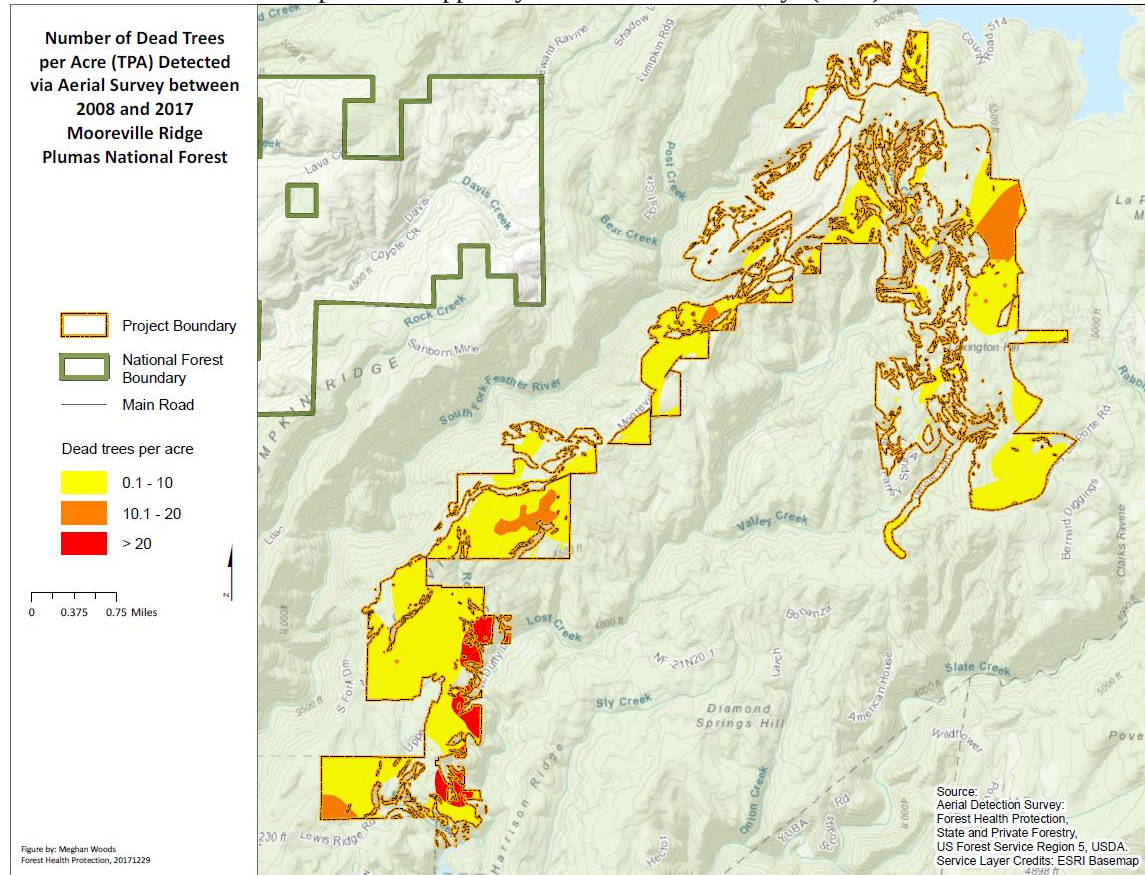


Figure 8. Overly dense mixed conifer stand with a high proportion of white fir.

Predicted climate change is likely to impact trees growing in this area over the next 100 years. Although no Plumas National Forest specific climate change models are available at this time, there is a general consensus among California models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (K. Merriam and H. Safford, *A summary of current trends and probable future trends in climate and climate-driven processes in the Sierra Cascade Province, including the Plumas, Modoc, and Lassen National Forests*). The risk of bark beetle-caused tree mortality will likely increase for all conifer species under this scenario, especially drought intolerant white fir.

Table 1. Acres with tree mortality, estimated dead trees per acre, estimated total # of dead trees from R5 Aerial Detection Surveys and Palmer Hydrologic Drought Index (PHDI) (CA Division 2) by water year (Oct-Sept) within the Mooreville project area.

Year	Acres	Dead Trees/Acre	Total # of Dead Trees	PHDI ¹
2017	1238	3.0	3719	2.45
2016	651	1.2	778	-1.78
2015	469	8.4	3956	-3.03
2014	29	0.6	18	-3.12
2013	10	1.2	12	-1.62
2012	387	12.3	4773	0.37
2011	511	3.2	1626	2.59
2010	169	5.2	877	0.19
2009	137	2.5	338	-2.69
2008	1	4.0	4	-2.74

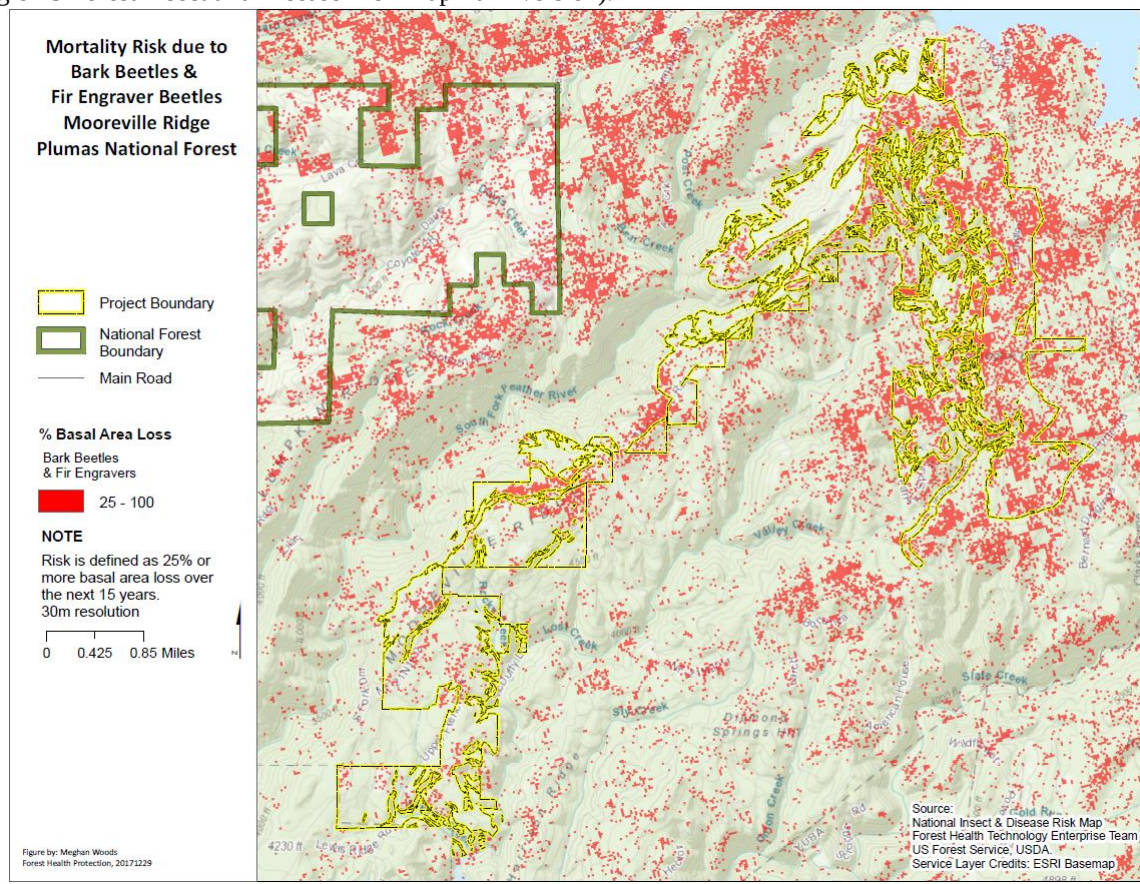
¹ Palmer drought values show a relationship to tree mortality. PHDI values ranging from -2.00 to -2.99 are considered moderate drought conditions. Severe drought conditions range from -3.00 to -3.99 and extreme drought conditions are below -4.00.

Discussion and recommendations

The Mooreville project area has become very dense, with a corresponding increase in white fir, through past management activities and with the exclusion of fire over the past 100+ years. With such a high density of white fir in the area, shade intolerant and fire resilient species such as ponderosa pine and black oak have declined due to excessive competition for sunlight, water and nutrients. These are not resilient forest conditions and will likely lead to unacceptable levels of tree mortality from bark beetles and disease or high severity wildfire.

The most recent National Insect and Disease Risk Map (2012) shows many stands within and adjacent to the Mooreville project that are currently at risk to high levels of bark beetle-caused tree mortality (Figure 9). This risk is based on precipitation, stand density and average tree diameter. This version of the map does not incorporate the risk of mortality from diseases such as Heterobasidion root disease and dwarf mistletoes which would increase the number of acres depicted. Improving the resilience of stands to future disturbance events through density, size class and species composition management will be critical to maintaining a healthy forested landscape in this area.

Figure 9. Risk of bark beetle-caused tree mortality based on precipitation, stand density and average diameter (Region 5 Forest Insect and Disease Risk Map 2012 version).



Thinning treatments are recommended to improve forest health conditions and increase resiliency to disturbance. Treatments should aim to reduce stand density to a level that significantly lowers the risk of bark beetle-caused mortality. In most cases, thinning to a relative density of 25 - 40% (relative to the maximum Stand Density Index, or SDI) for a specific conifer species or for a weighted composition of conifer species will effectively reduce competition for limited water and nutrients and reduce the susceptibility to future bark beetle-caused tree mortality for many years. The District should consider an SDI max of 450 for drier mixed conifer (Long and Shaw 2005) on south facing slopes and ridge tops and SDI max 550 (Long and Shaw 2012) for mixed conifer on more mesic aspects and down in drainages.

Many stands contain large diameter ponderosa pine, sugar pine and black oak. Thinning treatments that improve growing conditions for these more shade intolerant species, such as removing a large percentage of the white fir basal area around these trees, would increase their health and vigor, create opportunities for their successful regeneration and improve overall resiliency to disturbance agents (insects, disease, drought and fire). Removing competing trees from the base of large diameter pines combined with stand level thinning has resulted in a measured increase in annual increment growth in old growth ponderosa and Jeffrey pine on the Lassen National Forest (Hood et al 2017).

When planning thinning treatments, it should be recognized that the target stand density is an average to be applied across the landscape and some variability may be desired. Individual high value trees, such as mature pines and black oaks, should benefit by having the stocking around

them reduced to lower levels. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as forked and/or broken-topped trees, or on more mesic north-facing slopes. Incorporating the concepts of GTR 220 will address many of these issues and be consistent with Regional ecosystem restoration goals. Many of these methods are also consistent with past FHP recommendations for thinning in mixed conifer stands and their use is supported for the Mooreville project.

The presence of *Heterobasidion* root disease in white fir should be considered when developing silvicultural prescriptions. Root diseased true fir are at a higher risk for fir engraver attacks than uninfected trees during droughts. Leaving high numbers of root diseased trees in the overstory will likely lead to higher levels of mortality over the long-term, reducing canopy cover and increasing fuels. Leaving these trees will also reduce opportunities for successful regeneration of shade intolerant species that are not susceptible hosts to *H. occidentale*.

The best option for managing *H. occidentale* in white fir is to reduce its overall abundance in the stand and remove severely infected trees. Various sized openings can be created in the stand to facilitate planting of non-hosts such as ponderosa, Jeffrey and sugar pine. Placing these openings on known or suspected root disease pockets will enhance the effectiveness of this strategy for reducing overall infection levels. In addition, greatly reducing white fir stocking in stands that have a non-host overstory component will allow for natural non-host regeneration and create a more resilient species composition over time.

Sugar pine should be retained as much as possible during any thinning operation in order to preserve genetic diversity, especially white pine blister rust (*Cronartium ribicola*) resistant individuals. An exception to this would be thinning suppressed trees within pure sugar pine groups to reduce inter-tree competition. White pine blister rust, a non-native pathogen, has continued to weaken and kill this species over most of its range since its introduction into the Pacific Northwest in 1910. Identification and protection of local rust resistant trees for seed collection, if not already occurring, will aid in the future planting of rust resistant seedlings. Planting selected openings created through thinning operations with rust resistant stock would help insure this species persists in the area.

It is recommended that a registered borate compound be applied to all freshly cut conifer stumps >14" in diameter to reduce the chance of creating new infection centers of *Heterobasidion irregulare* and *H. occidentale* formerly referred to as P-type and S-type annosus root disease, through harvest activity. An exception to this recommendation would be in yellow pine/white fir stands or more pure white fir stands if there is already a high level of *Heterobasidion* root disease present as treating white fir stumps in heavily infected stands is ineffective. Red fir stumps should be treated unless further evaluations reveal an abundance of *H. occidentale* in red fir stands.

Considerations for Rx fire

If prescribed fire is used as a follow-up treatment to stand thinning, it may result in unacceptable levels of tree mortality; depending on management objectives. This mortality most often occurs as a direct result of cambium or crown injury to individual trees during the fire. Mature ponderosa pine, sugar pines and black oak are susceptible to lethal basal cambium damage during prescribed burns from the heat that develops in the deep duff and litter that accumulates at their bases. These duff mounds typically burn at a slow rate with lethal temperatures, causing

severe injury to the cambium which girdles the trees. To protect individual high-value large diameter pine and black oak from lethal cambium damage, raking the duff away from the bases of these trees before burning (within 24" of the bole and down to mineral soil) is recommended.

Potential for funding through the Western Bark Beetle Program

Forest Health Protection may be able to assist with funding for thinning and removing green material from overstocked areas within the Mooreville area. Thinning treatments that reduce stand density sufficient to lower the risk to bark beetle-caused mortality would meet the minimum requirements for Western Bark Beetle Program funding and would be supported by this evaluation. If you are interested in this competitive funding please contact me for assistance in developing and submitting a proposal.

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-252-6431.

/s/ Danny Cluck

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References:

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Insect and Disease Information

Western Pine Beetle

The western pine beetle, *Dendroctonus brevicornis*, has been intensively studied and has proven to be an important factor in the ecology and management of ponderosa pine throughout the range of the host species (Miller and Keen 1960). This insect breeds in the main bole of living ponderosa pine larger than about 8 inches DBH. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latitude and elevation, there can be from one to four generations per year.

Evidence of Attack

Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pitch tubes are formed on the tree trunk around the entry holes. Successful pitch tubes are red-brown masses of resin and boring dust. Relatively few, widely scattered white pitch tubes usually indicate that the attacks were not successful and that the tree should survive. Pheromones released during a successful attack attract other conspecifics. Attracted beetles may then spill over into nearby apparently healthy trees and overwhelm the tree with sheer numbers.

Life Stages and Development

These beetles pass through the egg, larval, pupal and adult stages during a life cycle that varies in length dependent primarily on temperature. Adults bore a sinuous gallery pattern in the phloem and the female lays eggs in niches along the sides of the gallery. The larvae are small white grubs that first feed in the phloem then mine into the middle bark where they complete most of their development. Bluestain fungi inoculates the tree during successful attacks, blocking trachids and vessels which contribute to the rapid tree mortality associated with bark beetle attacks.

Conditions affecting Outbreaks

Outbreaks of western pine beetle have been observed, and surveys made, in pine regions of the West since 1899 (Hopkins 1899; cited in Miller and Keen 1960). An insect survey completed in 1917 in northern California indicated that over 25 million board feet of pine timber had been killed by bark beetles. Information from surveys conducted in the 1930's indicated enormous losses attributed to the western pine beetle around that time. During the 1930's outbreak, most of the mortality occurred in stands of mature or overmature trees of poor vigor (Miller and Keen 1960). Group kills do not typically continue to increase in size through successive beetle generation as is typical with Mountain Pine Beetle and Jeffrey Pine Beetle. Rather, observations indicate that emerging beetles tend to leave the group kill area to initiate new attacks elsewhere.

The availability of suitable host material is a key condition influencing western pine beetle outbreaks. In northeastern California, drought stress may be the key condition influencing western pine beetle outbreaks. When healthy trees undergo a sudden and severe moisture stress populations of western pine beetle are likely to increase. Healthy trees ordinarily produce abundant resin, which pitch out attacking beetles, but when deprived of moisture, stressed trees cannot produce sufficient resin to resist the attack. Any condition that results in excessive demand for moisture, such as inter-tree competition, competing vegetation, or protracted drought periods; or any condition that reduces the ability of the roots to supply water to the tree, such as mechanical damage, root disease or soil compaction, can cause moisture stress and increase susceptibility to attack by the western pine beetle. Woodpeckers, predacious beetles, and low temperatures act as natural control agents when beetle populations are low (endemic populations).

Fir Engraver

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater than 4" in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack

Fir engravers bore entrance holes along the main stem, usually in areas that are > 4" in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the tree's defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development

In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year, however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

Mountain pine beetle

The mountain pine beetle, *Dendroctonus ponderosae*, attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 8 inches dbh. Extensive infestations have occurred in mature lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

Evidence of Attack

The first sign of beetle-caused mortality is generally discolored foliage. The mountain pine beetle begins attacking most pine species on the lower 15 feet of the bole. Examination of infested trees usually reveals the presence of pitch tubes. Pitch tubes on successfully infested trees are pink to dark red masses of resin mixed with boring dust. Creamy, white pitch tubes indicate that the tree was able to "pitch out" the beetle and the attack was not successful. In addition to pitch tubes, successfully infested trees will have dry boring dust in the bark crevices and around the base of the tree. Attacking beetles carry the spores of blue-staining fungi which develop and spread throughout the sapwood interrupting the flow of water to the crown. The fungi also reduces the flow of pitch in the tree, thus aiding the beetles in overcoming the tree. The combined action of both beetles and fungi causes the needles to discolor and the tree to die.

Life Stages and Development

The beetle develops through four stages: egg, larva, pupa and adult. The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is typical, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine. Females making their first attacks release aggregating pheromones. These pheromones attract males and other females until a mass attack overcomes the tree. The adults bore long, vertical, egg galleries and lay eggs in niches along the sides of the gallery. The larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

Conditions Affecting Outbreaks

The food supply regulates populations of the beetle. In lodgepole pine, it appears that the beetles select larger trees with thick phloem, however the relationship between beetle populations and phloem thickness in other hosts has not been established. A copious pitch flow from the pines can prevent successful attack. The number of beetles, the characteristics of the tree, and the weather affect the tree's ability to produce enough resin to resist attack. Other factors affecting the abundance of the mountain pine beetle include nematodes, woodpeckers, and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and pine mortality increases.

Heterobasidion Root Disease

Heterobasidion spp. is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees

presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species: *Heterobasidion occidentale* (also called the 'S' type) and *H. irregulare* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregulare* ('P' type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentale* ('S' type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentale* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

Dwarf mistletoe

Dwarf mistletoes (*Arceuthobium* spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occasionally vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been

measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

White pine blister rust

White pine blister rust is caused by *Cronartium ribicola* an obligate parasite that attacks 5-needled pines and several species of *Ribes* spp. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on *Ribes* spp. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to *Ribes* spp. where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other *Ribes* spp. throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on *Ribes* spp. leaves in the fall. Teliospores germinate in place to produce spores (sporidia) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to *Ribes* spp. to continue the cycle. Although blister rust may spread hundreds of miles from pines to *Ribes* spp., its spread from *Ribes* spp. back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers that have margins more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.